the *eucalyptus* vegetation, existed around us *independent of ourselves,* we might mourn our fate.

In conclusion, may we not say with some authority that the evidence set forth in this paper on our own vegetation is in favour of the *eucalyptus* being a fever-destroying tree ?

Art. VIII.—*On Some Processes of Scientific Reasoning.*

By F. J. Pirani, M.A., C.E.

[Read October 12th, 1874.]

Mr. President and Gentlemen,—

I have ventured this evening to offer a few remarks on "Ideal Construction" and "The Introduction of Metempirical Elements," processes of reasoning so named by Mr. G. H. Lewes in a recent work,* the importance of which has been overlooked by most writers on Inductive Logic, although it has been recognised by several Mathematicians and Physicists. In the course of my remarks, I shall have to briefly discuss the nature of some of the fundamental ideas of Mechanics—a subject on the borderland between Physics and Metaphysics, and one of great difficulty, if we may judge by the controversies it has occasioned amongst philosophers. But as science advances, it is well to examine its foundations from time to time, so that we may ascertain whether they are solidly built, and whether they are capable of bearing the weight of the continually increasing superstructure.

The method of Ideal Construction may be thus described:—The definitions and axioms of any branch of science, or, at all events, of any branch of science which has reached the Deductive stage, do not refer to the objects to which the results of the science are eventually applied, but to ideal conceptions of objects resembling the real ones, but of a nature much simpler and more capable of mathematical treatment. The conclusions arrived at by deductive reasoning, absolutely true for the ideal objects, will only be approximately true for the real ones, although sometimes the degree of approximation will be such that our senses are incapable of distinguishing it from absolute coincidence.

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* "Problems of Life and Mind," vol. i.

The Science of Geometry certainly pursues the method of Ideal Construction. Few mathematicians will agree with Mr. Mill that Geometry deals with the forms of real material objects. The subject-matter of Geometry is not the forms of real objects, but Ideal Conceptions derived therefrom. No material object fulfils the mathematical definition of a sphere —that all points on its boundary are equally distant from a certain point within the sphere—and consequently none of the propositions proved for geometrical spheres are rigorously true for material objects ; the more nearly a material object fulfils the definition of an ideal sphere, the more nearly are the properties of ideal spheres true for it, and the difference between some real objects and ideal spheres may be so small that, as far as our senses can detect, they rigorously possess the properties of the ideal conceptions. So, there is no such thing in nature as a straight line,—no lines such that if they coincide in two points, they coincide everywhere between those points,—although there are many material lines whose difference from straight lines is imperceptible to the senses.

The one Science which is as true of reals as of ideals is Arithmetic, or, at all events, that branch of Arithmetic which deals with Integral Number. Ten material bodies fulfil the definition of ten as accurately as ten ideal spheres and the deductions of Integral Arithmetic are absolutely true for external objects.

I now pass to the science of Dynamics. The fundamental conceptions of this Science are those of Matter and Force. I do not intend to discuss the various theories which have been held as to the nature and origin of these conceptions, but will endeavour, to the best of my ability, to give a clear account of my own opinions on the subject. Without entering into the general subject of the nature of Knowledge and Belief, it will be permitted me, I think, to divide Beliefs into two classes—Beliefs which have received verification from experience, and Beliefs which have not received such verification, either because they are, from their nature, incapable of it, or because the requisite experience has never presented itself. Would it be allowable to define the term Scientific Knowledge as denoting those Beliefs which have been verified by experience ?

Now, let us take such a belief as this—a table is before me ;—how can I proceed to test that belief ? I may look at the table ; I may touch it, and in other ways apply my senses to test my belief. But what is proved when I look

at the table? All that is proved directly is that certain states of consciousness, those involved in directing my eyes towards the table, are followed by certain other states of consciousness, the sight of the table. J. S. Mill, G. Grote, and others have very ably argued that all our knowledge is of states of consciousness and relations of co-existence and sequence between them. Certainly, such knowledge is the only sort of knowledge which admits of verification by experience, which can prove nothing directly, except relations between states of consciousness or phenomena. It must, however, be admitted that all our beliefs involve more than beliefs in such relations; that we have a very strong belief in the existence of something underlying phenomena, and which, in some sense, produces them. This underlying something is what is denoted by Matter. Mr. Mill himself admits that all our language involves the belief in Matter as something different from phenomena; and, truly, he would have a difficult task to perform who would endeavour to describe physical phenomena in intelligible language, which involved no beliefs except beliefs in relations between states of consciousness. So then, such a statement as, "A table six feet long is in this room," implies a large number of relations between states of consciousness, and also the existence of something different from those states, and which, partly, at all events, is the cause of them. The former portion of the belief admits of verification; the latter does not. If "matter" were suddenly annihilated, and some powerful spirit were to cause states of consciousness to succeed each other in our minds in the same order as they did before, we could not detect the difference. In dreams and hallucinations states of consciousness of a purely subjective origin excite the belief in External Matter as vividly as those presented in waking life.

In the use of words which involve the belief in matter, we have an example of the process which Mr. Lewes terms the Introduction of Metempirical Elements into beliefs, that is elements whose presence cannot be tested by experience.

Let us next consider the idea of Force. The origin of this idea is to be sought in voluntary muscular motion. If I move my arm, and introspectively observe the phenomenon, I find it may be divided into three parts.

1. The *volition* to move my arm.

2. The *effort* to move it.

3. Its motion.

Any one of these three may be isolated from the others. If I am paralysed, I may *will* to move my arm, but am incapable of exerting any *effort* to move it. If my legs are tied down, and the soles of my feet tickled, there will, quite independently of, and even in opposition to my will, be an *effort* to move my leg, which is not followed by sensible motion. If somebody else takes hold of my arm and pulls it, we have motion without being conscious of volition or effort.

Motion, however, is only one of the effects which effort can produce; there are others, *e.g.*, if I press my two hands together, I have effort producing pressure. Now, these effects which conscious effort can produce may be produced otherwise, as by tying a weight to my arm. Force is the name for anything which can produce the effects Effort produces; in fact Effort is a species of Force, though it does not follow that all Force is Effort. We may speak of a weight as a Force, or, as is sometimes done, we may speak of the weight as having a Force inherent in it. However we may picture Force to our imagination, it is a *metempirical* conception. All we can know of Force by experience is the phenomenal effects it produces. Yet, although a metempirical conception, the idea of Force is a most valuable one, and enables us to describe phenomenon much more clearly and concisely than could be done without employing it.

Having attempted an exposition of the nature of our conceptions of Matter and Force, I now proceed to show how Ideal Construction is employed in Dynamics.

Dynamics is generally divided into four parts—Dynamics of a particle, of a rigid body, of a fluid, and of a gas. Into each of these divisions Ideal Construction enters. There are no objects in nature which fulfil the definitions of a particle, rigid body, fluid, or gas. Yet there are many objects which, to our senses, differ so little from these Ideal conceptions, that the conclusion of Abstract Dynamics may be applied to them without practical error. We may also notice the Ideal conceptions of perfectly smooth bodies, flexible strings, &c. In dealing with the subject of *Impact*, an Ideal construction is employed, viz., the Idea of bodies which after coming into contact with each other, *immediately* rebound. As a matter of fact, an interval of time always

elapses between impulse and repulse; yet this interval is so short that it may practically be left out of account.

An ideal conception which enters into nearly every branch of Physics is that of an homogeneous body. A body may be homogeneous in various ways; if all the parts of a body have the same density, it is homogeneous as to density; if they have all the same chemical composition, it is chemically homogeneous. A body would be said to be absolutely homogeneous, or homogeneous in every respect, if any two parts of it differed in no properties except shape, size, and position, and such properties as are dependent on these. There is, however, no such thing as an homogeneous body, nor is there even any body which is homogeneous in respect to any particular quality. It is equally true that there is no body which is heterogeneous according to any simple mathematical law;—an ideal construction which is sometimes employed to give results more in accordance with facts than those obtained from the conception of simple homogeneity.

In those higher branches of Dynamics which deal with solids as not rigid, but susceptible of change of form under the action of Force, that is as elastic bodies, the conception of a particular sort of homogeneity, or of heterogeneity according to a definite law, is introduced. Such conceptions enable us to obtain results more consistent with facts than those derived from the conception of an absolutely rigid body; yet, partly from the mathematical difficulties of the subject, and partly from the irregular heterogeneous constitution of real objects, many practical problems of strain and stress in solids remain unsolved.

The Science of Heat assumes bodies to be homogeneous as to the powers of conduction, radiation, &c. Such assumptions afford examples of Ideal Construction. This Science also gives a very excellent illustration of the Introduction of Metempirical Elements.

Before the kinetic theory of Heat was accepted, what was meant by saying that a body was hot? The primary meaning was that a particular sort of sensation, that of heat, was produced in a person's mind when the body was placed in contact with, or brought near to his skin. But when it was discovered that all bodies which produced this phenomenon produced other peculiar phenomena when brought into proximity to other bodies, it was found

convenient to introduce the Metempirical conception of Heat as an unknown something whose presence produced these phenomena, just as Force denotes the unknown something which produces the phenomena of motion and pressure. We have, however, no such subjective knowledge of Heat as we have of one species of Force, viz., Effort. I must here notice an unfortunate ambiguity of language which employs the same word to denote the subjective sensation, heat, and the objective cause of that sensation. "Hot" has very different meanings in the sentences, "I am hot," and "this stone is hot." There is a similar ambiguity in the use of the words light, sound, &c.

Heat was by some conceived as a substance possessing all the qualities of a fluid except the quality of weight. This conception, was, however, inadequate to explain all the phenomena, and it and other ways of conceiving heat have now given place to the Empirical conception of Heat as a vibratory motion of particles.*

What has been said about Heat is, *mutatis mutandis*, applicable to the sciences of Light and Sound. As an example of Ideal Construction in Light, I may instance that of a body homogeneous in refractive power, or of a body heterogeneous in respect to that quality according to a simple law. How inaccurately deductions from this conception represent some physical phenomena is exemplified by the impossibility of determining with a close approximation to accuracy the effect of refraction on a heavenly body near the horizon. On the other hand, the results of mathematical calculation represent with practically perfect accuracy its effect on a body near the zenith.

The old metempirical conception of Light resembled very closely the metempirical conception of Heat; and the modern empirical conception of Light, as a vibratory motion of particles, resembles the empirical conception of Heat; indeed, it is now generally believed that Light and Heat are identical —that the same vibrations which, under certain conditions, produce the phenomena of heat, under other conditions produce the phenomena of light. There is not perfect agreement amongst physicists as to what it is, the

* In calling this conception Empirical, of course I do not mean that the vibration of molecules is a phenomenon which could be perceived by the senses, but that it differs from sensible phenomena in degree, and not in kind. It is empirical in the same sense as a million miles or the millionth part of an inch is empirical.

motion of whose particles constitutes Light. Some consider Light as the vibrations of ether—a substance different from any substance known empirically — while others consider it as the motion of particles of ordinary matter; others, I believe, hold a combination of these theories, and consider that the vibrations of ether may be communicated to the particles of ordinary matter.

Acoustics calls for no special consideration; like all other physical sciences, it employs the method of Ideal construction. Some of its conclusions agree very closely with real phenomena, while others do not accord very accurately with experience. The metempirical conception of Sound gave place, very early in the history of the Science, to the empirical conception of a vibration of the particles of sounding bodies.

The Ideal constructions employed in Electricity and Magnetism are of much the some character as those employed in the Sciences of Heat and Light. As one example I may mention that of soft iron, an abstraction convenient for expressing certain general laws of electricity, which are not accurately true for real iron. There are also metempirical conceptions of Electricity and Magnetism as the unknown causes of electric and magnetic phenomena. These two are, however, now considered to be one and the same. Electric and magnetic phenomena are intimately connected, and, whatever Electricity itself may be, we have no need to assume an additional entity as the cause of magnetic phenomena. None of the attempts to replace the metempirical conception of Electricity by an empirical one, similar to that to which Heat and Light have been reduced, can at present be considered perfectly satisfactory. The conception of Electricity as an imponderable fluid, although applicable to many problems, presents considerable difficulty. The most plausible theory seems to be that put forward by Mr. Clerk Maxwell, who considers the attraction between two electrified bodies to be caused by some sort of strain of a medium between them, rather than to any affection of the bodies themselves. From the action of magnetism on polarised light, he is led to believe that the ultimate cause of electrical phenomena is "the rotation of very small portions of the medium, each rotating on its own axis." *

* Clerk Maxwell's "Electricity and Magnetism," vol. ii. p. 408.

Chemistry is almost entirely based on Ideal construction. We popularly employ the term "gold" to denote various objects which possess certain properties of weight, color, &c., but the gold of the chemist is an ideal conception bearing the same relation to real gold as a geometrical sphere does to a real sphere; in fact, I believe I am correct in saying that no chemical element or definite chemical compound exists in nature, or can be produced artificially, in a state of absolute purity. The law of chemical combination in definite proportions is not accurately true for real substances, although in many experiments the deviation from the law is practically insensible. The same is true of the relation between the combining equivalent and specific heat of a gas, and, in short, of all numerical chemical laws.

Chemical affinity is a conception which is at present of an entirely metempirical nature. The phenomena of chemical composition and decompositions cannot be explained by the laws of ordinary physics, and it is convenient to assume an "unknown something," called Chemical Affinity, as the cause of these phenomena. Chemical Affinity is sometimes used in another sense, as a name for the peculiar relations between phenomena which it is in its other meaning the cause of—an unfortunate ambiguity—but the word has many companions in misfortune.

I may here allude to the fact that the separation of the different branches of Science from each other is purely an artificial one. All the relations between real material substances are complicated relations, involving dynamical, thermal, electrical, and, probably, chemical phenomena; and the perfect solution of the simplest mechanical problem would involve the application of all the Sciences which respectively deal with these phenomena. It is only by adopting the method of Ideal Construction that the different Inorganic Sciences can be separated from one another.

Passing now from inorganic to organic phenomena, in the Ideal Vertebral Skeleton of Owen we have a capital example of Ideal Construction. However, Biology has at present scarcely reached the deductive stage, and until it has become, to some considerable extent, a Deductive Science, it cannot be expected to illustrate the full value of that method of reasoning.

In Biology, we have the introduction of a metempirical element, which has been the cause of very violent controversy;—I refer to the idea of Life, Vitality, or Vital Force.

Now, the only phenomena exhibited by organic bodies which our senses can perceive are mechanical, thermal, electric, and chemical phenomena; but the *relations between organic phenomena* are different from the relations between physical and chemical phenomena. Although physics and chemistry may be competent to explain the actions which go on in a dead animal, they are incapable of explaining those which go on in a live one. If, then, we assume Vitality as an "unknown something" which is the cause of those changes which Mechanical Force, Heat, Electricity, and Chemical Affinity cannot be the cause of, we are only adopting a method which has been adopted and found useful in the lower divisions of Science. But let us remember that what Vitality is we know not, any more than we know what Matter is, or, than three hundred years ago, we knew what Light was. It is possible that as the metempirical conceptions of Heat and Light as abstract entities have been replaced by the empirical conception of vibratory motion, so Vitality may some day be replaced by an empirical concept; but, at all events, the day when this can be successfully accomplished seems to be far distant.

And as of Life, so of Mind. The relations between the phenomena exhibited by what are called intelligent beings are ultra-biological, as the relations between the phenomena exhibited by all organic beings are ultra-physical and ultra-chemical, and the introduction of a metempirical conception Mind or Intelligence as the cause of the ultra-biological relations is a Scientific process. But although the objective study of intelligent beings has as yet given us no certain information as to what Mind is, we have a subjective knowledge of, at all events, one species of Mind, as we have a subjective knowledge of one species of Force. We must not, however, too rashly assume that all Mind is the same as our Mind, as we must not assume that all Force is the same as that species of Force which is subjectively known as Effort. It is possible that some day Mind, as considered objectively, may be replaced by some empirical conception of vibration of nerve substance;—Mr. Herbert Spencer especially has made a very able attempt to accomplish this;* but that Mind as known subjectively is nothing but such vibrations is, to me at all events, an utterly inconceivable proposition.

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* *Vide* Herbert Spencer's "Principles of Psychology."

However, I fear I am getting into cloud-land, and, in conclusion, I think I am warranted in saying that I have shown that both Ideal Construction and the Introduction of Metempirical Conceptions are processes of frequent employment and of great value in Science, and that the thanks of both physicists and logicians are due to Mr. Lewes for having explicitly called attention to them.

Art. IX.—*On the Photographic Processes to be adopted in Observing the Transit of Venus.*

By R. L. J. Ellery, F.R.S., F.R.A.S.

[Read 12th October, 1874.]